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RESEARCH ARTICLE

State of art review on self compacting concrete using mineral admixtures

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Abstract
Concrete is the most widely used construction material because of its molded ability into any required structural form and shape due to its fluid behavior at early ages. In compaction the vibration is essential for achieving the workability, the required strength and durability of concrete. Inadequate compaction of concrete results in more number of voids. Affecting strength and extensive durability of structures, self compacting concrete (SCC) provides a solution to these problems. And it is able to compact itself without any additional vibration. In this concrete, cement replacement with some material like fly ash, metakaolin, ground granulated blast furnace slag (GGBS) etc. because to reduce 5–7% of CO_2 emissions in cement and due to the curing of concrete large amount of water is required. To overcome the high consumption of water it is needed to study the self-curing concrete. This investigation will shown scientific basis for potential design of SCC materials for concrete structures.

Keywords Concrete · Self compacting concrete · Metakaolin · Curing · Compaction and structures

1 Introduction

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens (cures) over time. In the past the lime based cement binders were often used, such as lime putty, but sometimes with other hydraulic cements, such as calcium aluminates cement or with Portland cement to form Portland cement concrete. Many other non cementations' types of concrete exist with different methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces and polymer concretes that use polymers as a binder. When aggregate was mixed with dry portland cement and water, the mixture forms fluid slurry that is easily poured and molded into shape. The cement reacts with water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Often, additives are included in the mixture to improve the physical properties of wet mix or finished material. Most concrete was poured with reinforcing materials embedded to provide a tensile strength and yielding reinforced concrete. Concrete is one of the most frequently used building materials. Its usage worldwide is twice that of steel, wood, plastics and aluminum combined. Globally, the ready-mix concrete industry, the largest segment of concrete market, is projected to exceed $600 billion in revenue by 2025 [1, 2].

1.1 Self compacting concrete

Self-consolidating concrete or self-compacting concrete (commonly abbreviated to SCC) is a concrete mix which has a low yield stress, high deformability, good segregation resistance (prevents separation of particles in the mix) and moderate viscosity (necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets). In everyday terms, when poured, SCC is highly fluid mix with the following distinctive practical features—it flows very easily within and around the formwork, can flow through obstructions and around corners "passing ability" is close to self-leveling (although not actually self-leveling), does not require vibration or tamping after pouring and follows the shape and surface texture of a mold (or form) very closely once set. As a result, pouring SCC is also much less

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labor-intensive compared to standard concrete mixes. Once poured, SCC is usually similar to standard concrete in terms of its setting and curing time (gaining strength) and strength. SCC does not use a high proportion of water to become fluid in fact SCC may contain less water than standard concretes. Instead, SCC gains its fluid properties from an unusually high proportion of fine aggregate, such as sand typically 50%, combined with super plasticizers (additives that ensure particles disperse and do not settle in the fluid mix) and viscosity-increasing admixtures (VEA) [3, 4].

Ordinarily concrete is a dense, viscous material when mixed and used in construction, requires the use of vibration or other techniques known as compaction to remove the air bubbles cavitations, and honeycomb-like holes, especially at the surfaces, where air has been trapped during pouring. This kind of air content (unlike that in aerated concrete) is not desired and weakens the concrete if left. However it is laborious and takes time to remove by vibration and improper or inadequate vibration can lead to undetected problems later. Additionally some complex forms cannot easily be vibrated. Self-consolidating concrete is designed to avoid this problem, and not require compaction, therefore reducing labor, time and possible source of technical and quality control issues. SCC was conceptualized in 1986 by Prof. Okamura at Kochi University, Japan, at a time when skilled labor was in limited supply, causing difficulties in concrete-related industries [5, 6]. The first generation of SCC used in North America was characterized by the use of relatively high content of binder as well as high dosages of chemicals admixtures, usually super plasticizer to improve flow capacity and stability. Such high-performance concrete had been used in repair applications and for casting concrete in restricted areas. The first generation of SCC was characterized and specified for specialized applications. SCC can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may be impossible to cast, giving a far superior surface than conventional concrete. The high cost of material use in concrete continues to hinder its broad use in various segments of construction industry, including commercial construction; however the productivity economics take over in certain favorable performance benefits and works out to be economical in pre-cast industry. The incorporation of powder, including supplementary cementations' materials and filler, can increase the volume of paste, hence improving deformability and also increase the cohesiveness of paste and stability of concrete. The reduction in cement content and increase in packing density of materials finer than 80 µm, like fly ash etc. can reduce the water-cement ratio and high-range water reducer (HRWR) demand. The reduction in free water can reduce the concentration of viscosity-enhancing admixture (VEA) necessary to ensure proper stability during casting and thereafter until the onset of hardening. It has been demonstrated that a total fine aggregate content ("fines", usually sand) of about 50% of total aggregate is appropriate in an SCC mix [7, 8].

1.1.1 Self compacting concrete mix design requirements

1.1.1.1 High volume of paste As SCC concrete undergoes self-compaction by its own weight, it has to attain adequate filling ability so that the mix reaches every area. Friction between the aggregates restricts this spreading hence the filling capacity. This issue was solved by increasing the paste content in SCC mix design in a range of 300–400 l/m^3. The volume of paste implies the combination of cement, water additions and air. This increase in paste helps separation of aggregates and easy movement of the mix.

1.1.1.2 High volume of fines (< 80 µm) SCC must be designed for sufficient workability to show the property of self-compaction. This workability must not bring segregation and bleeding issues. To limit these risks, SCC is designed to have a large number of fines in a range of 500 kg/m^3. Excessive fines in the form of cement bring chances of an increased heat of hydration. For this, a part of fines was replaced by pozzolans or mineral admixtures like silica fume or fly ash. The strength and durability requirements of SCC concrete govern the volume of filler fines added to the mix.

1.1.1.3 High dosage of super plasticizers Super plasticizers are introduced in SCC to obtain the fluidity and workability. Nevertheless, a high dosage near the saturation amount can increase the proneness of concrete to segregate. The increase of workability by using super plasticizers won't leave segregation or bleeding issues.

1.1.1.4 Use of viscosity modifying agent The viscosity modifying agent in SCC mix design has the same objective as that of fine particles. These help to attain the flow capacity property for concrete without segregation and bleeding issues. These hold the mix by thickening the paste and holding the water with skeleton created by these agents. Viscosity modifying agents are cellulose derivatives, polysaccharides or colloidal suspensions. The introduction of such products in SCC seems to be justified in the case of SCC with the high water to binder ratio (for e.g. residential building). On the other hand, they may be less useful for high-performance SCC (strength higher than 50 MPa) with low water to binder ratio. Viscosity agents make SCC less sensitive to water variations in water content of aggregates occurring in the concrete plants.

1.1.1.5 Less coarse aggregate To increase the passing capacity of SCC, the volume of coarse aggregate added was less. The coarse aggregate used can be naturally rounded, crushed or semi-crushed aggregate. The coarse aggregate has a main role in increasing the packing density of SCC. So that the volume of coarse aggregate not too high or too low. The size of coarse aggregate can be use between 10 and 20 mm. With the increase in size of coarse aggregate, the passing capacity was decreases. The choice of higher aggregate size is thus possible but only with the low reinforcement content.

1.1.1.6 Addition of admixtures Admixtures added to SCC can have a retarding effect on the strength and temperature development in the fresh concrete and this has to keep in mind in the construction process. Suppliers of admixture can produce various admixtures suitable for different weather conditions and temperatures. The additions have to be performed based on the guidelines provided by the admixtures.

1.2 Methods of testing self compacting concrete

The tests methods presented here are advised specifically for self compacting concrete. Existing rheological test procedure have not considered here, though the relationship between results of tests and rheological characteristics of the concrete is likely to figure highly in the future work, including the standardization work.

In considering these tests there are number of points which should be taken into account:

- There is no clear relation between the test results and performance on site.
- There is little precise data, therefore no clear guidance on compliance limits.

A concrete mix can only be classified as self compacting concrete if the requirements for all following workability properties are fulfilled.

- Filling ability.
- Passing ability.
- Segregation resistance.

1.2.1 Slump flow test

The slump flow tests method to determine the consistency of fresh concrete. The flow table test as shown in Fig. 1 is used to identify the transportable moisture limit of solid bulk cargoes. The slump flow test is used assess the horizontal free flow of self compacting concrete in the absence of obstructions. The test method was based on the determining of slump [9, 10, 94].

1.2.2 V-funnel test

V-funnel test on self compacting concrete is used to measure the flow capacity. But the flow capacity of concrete is affected by its other properties as well which may affect the flow capacity of concrete during testing. The V-funnel test apparatus is shown in Fig. 2. The UTC-0540 V funnel apparatus was used to evaluate the flow time of freshly mixed self-compacting concrete. This standard covers the method of funnel testing for average flow-through speed, relative flow-through speed and flow-through indices of self-compacting concrete with a maximum coarse aggregate size of 25 mm or less. The more increase in flow time after the concrete has remained at rest for five minutes, the greater will be the concrete's susceptibility to segregation. Further, non-uniform flow of concrete from the funnel suggests a lack of segregation resistance [11, 12, 95].

Fig. 1 Slump flow table apparatus

Fig. 2 V-funnel test apparatus

1.2.3 L-box test

This test assesses the flow of concrete and also the amount to which it's subjected to blocking by the reinforcement. The test apparatus consist of rectangular section box in the shape of an 'L', with a vertical and horizontal section, separated by a movable gate, in front of which vertical length of reinforcement bar are fitted [96]. The L-box test apparatus is shown in Fig. 3.

1.2.4 U-box test

U box test is used to measure the filing capacity of self compacting concrete. U box test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Some time the apparatus is called a "box shaped" test. The apparatus consists of vessel that is divided by a middle wall into two compartments; an opening with a sliding gate is fitted between the two sections. The apparatus of U-box test is shown in Fig. 4. This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of the filling capacity [13, 14, 97].

2 Self curing concrete

Construction industry is growing day by day even in the remote areas and desert regions. Even India and other countries are facing a lot of problems in supplying drinking water to their citizens. Hence construction industries are under pressure in finding out alternative curing methods of curing concrete. Self curing concrete is the one which can meet the present and future requirement of curing concrete. Concrete is primarily used in building material. For curing of concrete, require large amount of water. Concrete is a universal construction material and cement, water and aggregates are its ingredients. The strength of concrete depends upon the properties of its constituents and mix proportions and amount of hydration in the concrete. For the complete hydration require good quality of water in certain amount. Curing is the maintenance of a satisfactory moisture content

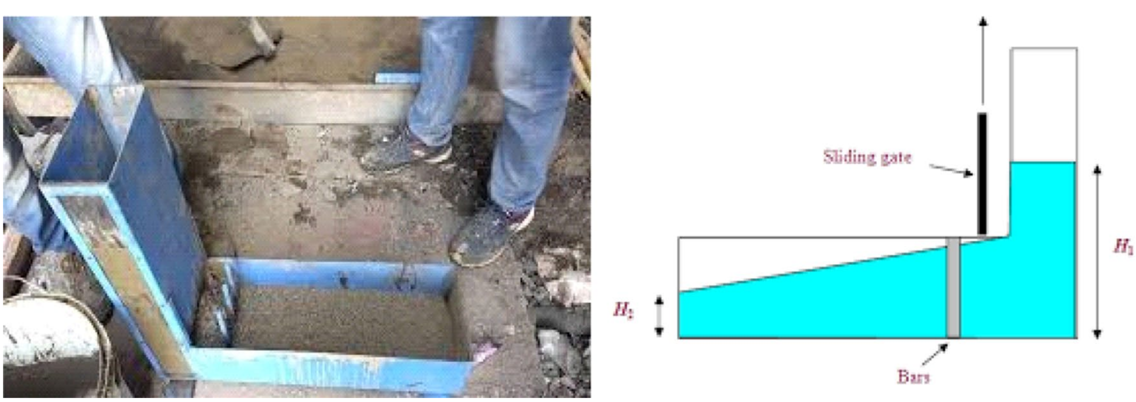

Fig. 3 L-box test apparatus

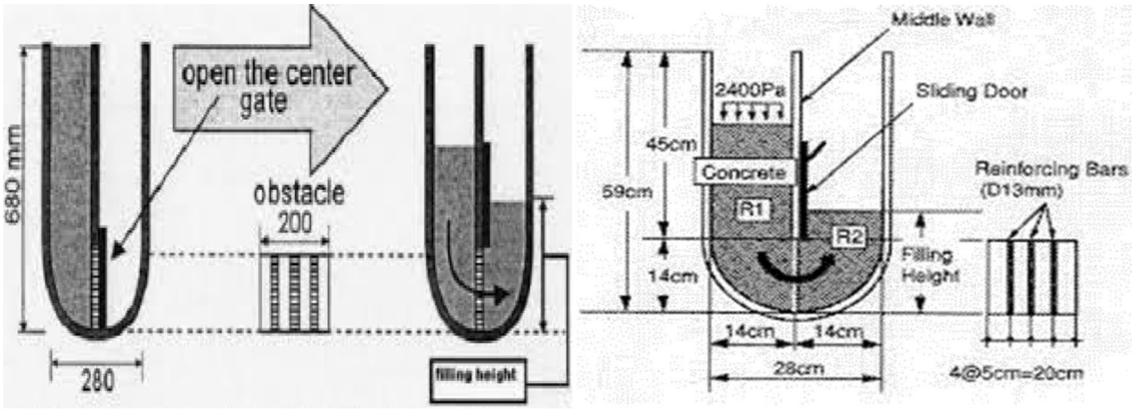

Fig. 4 U-box test apparatus

and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability and resistance to freezing and thawing etc. As per ACI-308R the term "curing" is frequently used to describe the process by which hydraulic cement concrete matures and develop hardened properties over time as a result of continued hydration of cement in the presence of sufficient water and heat [15, 16]. As per IS: 456–2000 Curing is the process of preventing loss of moisture from the concrete. Curing of concrete plays a major role in the developing strength and hardness of concrete, which may leads to improvement in the durability and performance. The various internal and external self curing process of concrete is shown in Fig. 5. The effect of various curing agent on the performance of concrete is discussed below. Curing is a process of promoting the hydration of cement and consists of control in temperature and moisture movement into the concrete [17, 18].

Poor curing practices adversely affect the certain properties and performance in concrete. Proper curing of concrete is essential to obtain the maximum durability, especially if the concrete is exposed to severe conditions. Even when good quality concrete is placed on the job site, curing is necessary to ensure the concrete provides good service over the life of structure. So for attaining good strengths of concrete need best quality of curing with portable water. It has been pointed out earlier that curing does not mean application of water; it means the promotion of uninterrupted and progressive hydration. It is also pointed out that the quantity of water, normally mixed for making concrete is sufficient to

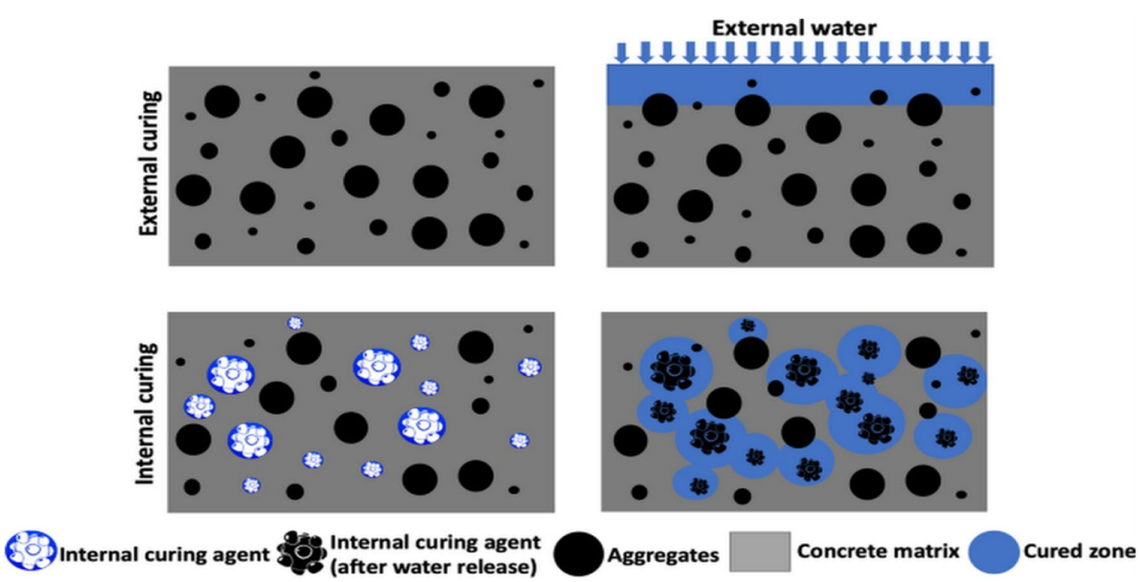

Fig. 5 Self curing processes of concrete with internal curing agent

hydrate the cement content. Concrete in which the mixing water was restricted by the means of some chemical compounds, to go out from the concrete body is known as “self curing concrete”. Sometimes works are carried out in place where there is acute shortage of water and application of water in curing is not possible for the reasons of economy. Prevention of moisture loss from the surface of flat concrete works such as highways and airports have been challenging task for construction managers [19, 20].

2.1 Need for self curing

Self-compacting concrete, which flows under its own weight and doesn’t require any external vibration for compaction, has revolutionized concrete placement. Such concrete should have relatively low yield value to ensure high flow ability, a moderate viscosity to resists segregation and bleeding and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability [21, 22].

2.2 Advantages of self curing concrete processes

- When properly applied, provides a premium-grade film, which optimizes the water retention.
- Protects by reflecting the sun’s rays to keep the concrete surface cooler and prevent excessive heat build-up, which can cause thermal cracking.
- Furnished as a ready-to-use, true water-based compound. Produces hard, dense concrete minimizes hair checking, thermal cracking, dusting and other defects.
- Offers a compressive strength significantly greater than improperly or uncured concrete.
- Improves resistance to the abrasion and corrosive actions of salts and chemicals minimizes the shrinkage.

2.3 Self curing agents

- Water-soluble polymers.
- Polyethylene glycol-200.
- Polyethylene glycol-4000.
- Polyethylene glycol-600.
- Liquid paraffin wax(light).
- Liquid paraffin wax(heavy).
- Super absorbent polymers.

3 Application of fly ash in self curing processes

Fly ash or flue ash, also known as pulverized fuel ash in the United Kingdom, is a coal combustion product that is composed of particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of boiler’s combustion chamber (commonly called a firebox) is called bottom ash. In modern coal-fired power plants, the fly ash was generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach chimneys. Together with bottom ash removed from the bottom of boiler, it is known as coal ash. Depending upon the source and composition of coal being burned, the components of fly ash vary considerably, but fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. The minor constituents of fly ash depend upon the specific coal bed composition but may include one or more of the following elements or compounds found in the trace concentrations (up to hundreds ppm): arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium and vanadium, along with very small concentrations of dioxins and PAH compounds. It also has unburnt carbon. Fly ash utilization, especially in concrete, has significant environmental benefits including: (1) Increasing the life of concrete roads and structures by improving concrete durability, (2) Net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement (3) Reduction in amount of coal combustion products that must be disposed in landfills and (4) Conservation of other natural resources and materials [23–25].

3.1 Classification of fly ash

3.1.1 Class F

The burning of harder, older anthracite and bituminous coal typically produces class “F” fly ash. This fly ash is pozzolanic in nature and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class “F” fly ash requires a cementing agent, such as portland cement, quicklime or hydrated lime mixed with water to react and produce cementations compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to a Class F ash can form a geopolymer. The chemical property of fly ash is discussed in Table 1.

3.1.2 Class C

Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20%

Table 1 Chemical properties of fly ash

Components	Percentage
Silicon dioxide SiO_2	64.58
Aluminum dioxide Al_2O_3	25.89
Ferric oxide Fe_2O_3	5.27
Calcium oxide CaO	3.59
Magnesium oxide MgO	0.26
Sodium oxide Na_2O	0.027
Potassium oxide K_2O	0.041
Sulfur trioxide SO_3	0.34

lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate contents are generally higher in Class C fly ashes [26, 27].

3.2 Advantages of fly ash

- Reduced water content for a given workability or improved workability at the same water content.
- The rate of bleeding was reduced while workability was increased.
- Improved long term strength and durability performance.
- Lower shrinkage and porosity as a result of the lower water content.
- Lower permeability and better resistance to sulphate attack.

The importance of low water cement ratio for increasing durability of concrete has long been accepted. Low water content leads to a low workability of the fresh concrete and if this concrete is not properly compacted, the durability of structures will be impaired. A proper design of a self-compacting concrete requires considerably more fines content as compared to the traditional concrete. Therefore, large volumes of fly ash, partially in substitution of cement and partially as filler, can be employed in producing self-compacting concrete. The high flow ability is obtained by the addition of super plasticizer with an extremely high efficiency based on polycarboxylatether or with a combination of admixtures enhancing flow ability, viscosity and stability. The use of fly ash and blast furnace slag in self-compacting concrete reduces the dosage of super plasticizer needed to obtain similar slump flow as for concrete made with Portland cement only. Also, the use of fly ash improves rheological properties and reduces cracking of concrete due to heating the hydration of cement. The influence of supplementary cementations' materials on workability and replacement of cement by fly ash can significantly improve rheological properties [28–30].

The making of self-compacting concrete more affordable for the construction market by replacing high volumes of portland cement by fly ash. The bleeding water increased with an increase in the water-to cementitious materials ratio. The increase percentage of fly ash at total weight of the cementitious materials did not significantly influence the bleeding water of the self-compacting concrete. The potential of high-volume fly ash self compacting concrete system for reducing the temperature rise in large concrete members due to its low cement content and slow reaction process of fly ashes. The higher temperature in the control concrete, and lower temperature in self-compacting concrete incorporating high volumes of fly ash. The minimum replacement of fly ash can be investigated to achieve higher tensile and flexural strength. Self-compacting concrete is able to flow and consolidate under its own weight and is deaerated almost completely while flowing in the formwork. It is cohesive enough to fill the formwork of any size and shape without segregation or bleeding. The compressive strength of SCC is found to be higher than that of normal concrete [31, 32].

4 Application of metakaolin in self curing processes

Metakaolin is the anhydrous calcined form the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than the cement particles, but not as fine as silica fume. The manufacturing process of metakaolin is shown in Fig. 6. The T-O clay mineral kaolinite does not contain interlayer cations or interlayer water. The temperature of dehydroxylation depends on the structural layer stacking order. Disordered kaolinite dehydroxylates between 530 and 570 °C, ordered kaolinite between 570 and 630 °C. Dehydroxylated disordered kaolinite shows higher pozzolanic activity than ordered. The dehydroxylation of kaolin to metakaolin is an endothermic process due to the large amount of energy required to remove the chemically bonded hydroxyl ions. Above the temperature range of dehydroxylation, kaolinite transforms into metakaolin, a complex amorphous structure which retains some long-range order due to layer stacking. Much of the aluminum is octahedral layer becomes tetrahedrally and pentahedrally coordinated. In order to produce a pozzolan (supplementary cementations material) nearly complete dehydroxylation must be reached without overheating, i.e., thoroughly roasted but not burnt. This produces an amorphous, highly pozzolanic state, whereas overheating can cause sintering, to form a dead burnt, nonreactive refractory, containing mullite and a defect Al-Si spinel. The chemical property of met kaolin is discussed in the Table 2 [33, 34].

The reported optimum activation temperatures vary between 550 and 850 °C for varying durations; however the

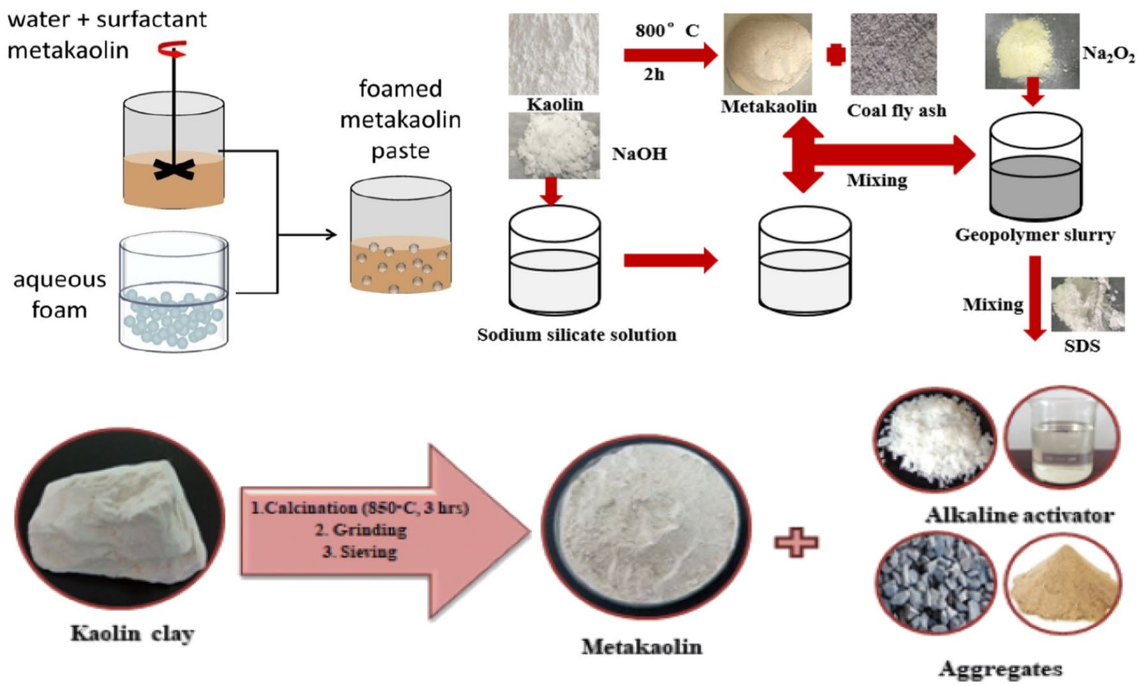

Fig. 6 Manufacturing of metakaolin in self curing process

Table 2 Chemical properties of metakaolin

Components	Percentage
Silicon dioxide (SiO_2)	53
Aluminum dioxide (Al_2O_3)	44
Ferric oxide (Fe_2O_3)	1.7
Calcium oxide (CaO)	0.7
Magnesium oxide (Mgo)	0.6

range 650–750 °C is most commonly quoted. In comparison with other clay minerals kaolinite shows a broad temperature interval between dehydroxylation and recrystallization, much favoring the formation of metakaolin and use of thermally activated kaolin clays as pozzolans. Also, because the octahedral layer is directly exposed to the interlayer (in comparison to the instance T-O-T clay minerals such as smectites), structural disorder was attained more easily upon heating [35, 36].

4.1 Advantages of metakaolin

- Increased compressive and flexural strengths.
- Reduced permeability (including chloride permeability).
- Reduced potential for efflorescence, which occurs when calcium is transported by water to the surface where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue.
- Increased resistance to chemical attack.
- Increased durability.
- Reduced effects of alkali-silica reactivity (ASR).
- Enhanced workability and finishing of concrete.
- Reduced shrinkage, due to "particle packing" making concrete denser.
- Improved color by lightening the color of concrete making it possible to tint lighter integral color.

4.2 Performances study of various metakaolin concretes

The physical transformation of powdered K associated with the rapid dehydroxylation of Kaol during flash calcinations leads to physical changes of MKaol in the MK, compared to traditional MK as described in the literature. Metakaolin is refined kaolin clay that is fired under carefully controlled conditions to create an amorphous alumino silicate that is reactive in concrete. Like pozzolans such as silica fume, fly ash and blast furnace slag, metakaolin reacts with the calcium hydroxide by-products produced during cement hydration. The particle size of metakaolin is generally smaller than the cement particles, though not as fine as silica fume. Silica fume as a mineral admixture for concrete has great attention both in research and application. It is a by-product resulting from the reduction of high purity quartz in an electric arc furnace during the production of silicon metal or silicon alloys. Metakaolin is another pozzolanic material which is a highly efficient pozzolanas and reacts with the excess calcium hydroxide resulting from the cement hydration, to produce calcium silicate hydrates and calcium alumino silicate hydrates. The literature study of various metakaolin concrete is discussed in the Table 3 [37, 38].

The use of pozzolanas for making concrete was considered efficient, as it allows the reduction of cement consumption while improving the strength and durability properties of the concrete. MK or SF when used as a partial replacement of cement is known to improve both the mechanical characteristics and durability of concrete. Hence by partially replacing cement with MK or SF not only reduces carbon dioxide emissions but also increases the service life of constructions. Several researchers have investigated the effect of silica fume and Metakaolin by replacing the cement on various parameters, which includes fresh, mechanical and durability properties of concrete. The effect of metakaolin at a constant water/binder ratio of 0.3 on mechanical and durability properties of high strength concrete was studied. Inclusion of MK increases the compressive, tensile, flexural strengths and modulus of elasticity of concrete considerably; however, the workability was slightly compromised. Consistency of concrete was decreased with the increase in MK content without super plasticizer, but the use of super plasticizer was very essential in concrete containing fine particles like MK or SF to achieve well dispersion and better results. The compressive strength and other hardened properties of concrete with MK were higher than that of reference concrete at the same W/Cm ratio [39, 40].

According to Chand et al. (2005) the effect of using paraffin wax as a self curing compound in self compacting concrete mixes and SCC mixes with w/c ratios of 0.3, 0.45, 0.55 without and with LPW. The maximum compressive strength is 75.73 N/mm^2 for conventional water curing at 28 day [24]. In Chand et al. (2014) studied the paraffin wax as an internal curing agent in ordinary concrete. The experimental work was carried out to establish the suitability of curing compound and its dosage in different grades of concrete. The maximum compressive strength is 63.2 N/mm^2 for water curing at 28 days [25]. According to Ananthi et al. (2017) the effect of polyvinyl alcohol on the strength characteristics of self curing concrete to reduce water quantity in curing period and mixes with various dosages of curing agents of 0.1%, 0.5%, 0.6% and 1%. The result compressive strength is 34 N/mm^2 for 0.6% of SRP, 0.50% of PVA and 30% of pond ash replace of cement at 28 days [26]. The Shafeeque et al. (2016) studied the strength comparison of self curing concrete and normal curing concrete in this program designed to investigate that the strength of self curing concrete by adding PEG-600 at 0.5%, 1%, 1.5% and 2% by weight of cement and compare strength characteristics of normal curing concrete and self curing concrete. The result of maximum compressive strength is 29.20 N/mm^2 for 1% of PEG and M_{25} concrete at 28 days. And tensile strength is 3.83 N/mm^2 for 1% of PEG at 28 days [27]. According to Madduru et al. (2020) studied the hydrophobic chemicals as self curing agents in self compacting concrete, the experimental program consists of designing SCC of M_{60} grade and casting cubes, cylinder and prisms to determine the strength and durability properties and by adding the hydrophobic chemicals at 0.5%, 1%, 1.5% and 2% by weight of cement. The maximum compressive strength is 74.55 N/mm^2 and tensile strength is 8.3 N/mm^2 and flexural strength is 7.9 N/mm^2 for conventional water curing at 28 days [28].

According to Mohan Raj et al. (2014) studied that the two concrete mixes have been adopted with the similar w/c ratio. Self curing agent was added to one mix and other mix was without any curing agent. The compressive strength is 33.5 N/mm^2 for M_{30} grade and self curing agent is 0.3% then attained maximum strength [29]. In Kadhum et al. (2014) studied that the effect of metakaolin and fly ash on properties of self compacting concrete through accelerated curing and experimental program was designed to produce a high strength concrete by adding several combinations of fly ash and metakaolin. The result of maximum compressive strength is 58.9 N/mm^2 for 40% of metakaolin by the weight of cement at 28 days [30]. According to Prabhu et al. (2018) studied that the behavior of self-compacting concrete with cement replacement materials the structural behavior of M_{30} grade self compacting concrete cast by partial replacement of cement with cement replacement materials. The maximum compressive strength is 39.6 N/mm^2, tensile strength is 8.35 N/mm^2 and flexural strength is 2.28 N/mm^2. The 25% of fly ash and wood ash are weight in cement at 28 days [31]. In Kumar et al. (2013) studied that the self-curing concrete effect of variation of strength parameter i.e., the compressive strength, tensile strength and flexural strength were studied for different dosage of self curing agent and compacted with convention curing concrete. The result of compressive strength is 43.11 N/mm^2 for 0.3% of SAP at 28 days and tensile strength is 4.94 N/mm^2 and flexural strength is 6.425 N/mm^2 and 0.2% of SNP at 28 days [32]. According to Yoganantham et al. (2015) studied that the self-compacting self curing concrete with fly ash and m-sand to study that the compressive strength of self curing concrete by varying the percentage of PEG from 0.5 to 0.2% by weight of cement for M_{25} grade of concrete. The maximum compressive strength is 35.01 N/mm^2 for 1% of PEG at 28 days [33].

4.3 Metakaolin materials applications

The physical, chemical and mechanical characteristics of metakaolins obtained from an industrial flash calciner, in order to compare their properties with standard industrial metakaolin produced in a rotary kiln calciner. Three kaolins with different levels of purity were calcined by two different methods to give six different metakaolins for the

Table 3 Literature study of various metakaolin concretes

S.N.	Materials	Chemicals	Experimental condition	Results	References
1	Cement, fine aggregate, coarse aggregate, fly ash, silica fume and water	Liquid paraffin wax poly carboxylic ether	The self curing compound of paraffin wax in self compacting concrete mixes and SCC mixes with w/c ratios of 0.3, 0.45 and 0.55 without and with LPW	Compressive strength = 75.73 N/mm^2 for conventional water curing at 28 days	Chand et al. [40, 42]
2	Cement, fine aggregate, coarse aggregate and water	Liquid paraffin wax, solid paraffin wax	The suitability of curing compound and dosage in different grades of concrete	Compressive strength = 63.2 N/mm^2 for water curing at 28 days	Chand et al. [25]
3	Cement, fine aggregate, coarse aggregate, water and pond ash	Super absorbent polymer, polyvinyl alcohol	The effect of polyvinyl alcohol on the strength characteristics of self curing concrete to reduce the water quantity in curing period	Compressive strength = 34 N/mm^2 for 0.6% of SRP, 0.50% of PVA and 30% of pond ash at 28 days	Ananthi et al. [26]
4	Cement, fine aggregate, coarse aggregate and water	Polyethylene glycol-600	The self curing concrete by adding PEG-600 at 0.5%, 1%, 1.5% and 2% by weight of cement and compare strength characteristics of normal concrete and self curing concrete	Compressive strength = 29.20 N/mm^2 for 1% of PEG and M_{25} concrete at 28 days. Tensile strength = 3.83 N/mm^2 for 1% PEG at 28 day	Shafeeque et al. [27]
5	Cement, fine aggregate, coarse aggregate, fly ash, micro silica and water	Polyethylene glycol-4000, light liquid paraffin wax polycasboxate ether	The experimental program consists of designing self compacting concrete of M_{60} grade and casting cubes, cylinder and prisms	Compressive strength = 74.55 N/mm^2. Tensile strength = 8.3 N/mm^2. Flexural strength = 7.9 N/mm^2 for 28 days	Madduru et al. [28]
6	Cement, fine aggregate, coarse aggregate and water	Polyethylene glycol-400	Self curing agent was added to one mix and other mix was without any curing agent. The experimental study was designed to produce a high strength concrete by adding several combinations of fly ash and metakaolin	Compressive strength = 33.5 N/mm^2 for M_{30} grade and self curing concrete 0.3%	Mohan Raj et al. [29]
7	Cement, fine aggregate, coarse aggregate, fly ash, metakaolin and water	Glenium-51	The self curing concrete by adding Glenium-51 at 1.5%, 2%, 2.5% and 3% by weight of cement and compare strength	Compressive strength = 58.9 N/mm^2 for 40% metakaolin by wt. of cement at 28 days	Kadhum et al. [30]
8	Cement, fine aggregate, coarse aggregate, wood ash, fly ash and water	Masterglenium sky B233	The M_{30} grade self compacting capacity of concrete cast by partial replacement of cement with cement replacement materials	Compressive strength = 39.6 N/mm^2. Tensile strength = 8.35 N/mm^2. Flexural strength = 2.28 N/mm^2. For 25% fly ash and 25% wood ash by the weight of cement at 28 day	Prabhu et al. [31]
9	Cement, fine aggregate, coarse aggregate and water	Conplast SP430, super absorbent polymer	The effect of variation strength parameter i.e. compressive strength, tensile strength and flexural strength at different dosage of self curing agent	Compressive strength = 43.11 N/mm^2 for 0.3% of SAP at 28 days. Tensile strength = 4.94 N/mm^2. Flexural strength = 6.425 N/mm^2 at 28 day	Kumar et al. [32]

Table 3 (continued)

S.N.	Materials	Chemicals	Experimental condition	Results	References
10	Cement, fine aggregate, coarse aggregate, fly ash, m-sand and water	Glenium B233, PEG-400	The compressive strength of SCC by varying percentage of PEG from 0.5 to 0.2% by wt. of cement in M_{25} grade concrete	Compressive strength = 35.01 N/mm^2 for 1% of PEG at 28 days	Yoganantham et al. [33]

study. The results showed that the method of calcinations did not affect the chemical composition of metakaolins formed but did influence their physical properties and performance as a supplementary cementations material when blended with Portland cement and in geo-polymer synthesis. Flash metakaolins have a lower water demand than rotary metakaolins, which can be explained by the morphological properties of flash metakaolin, induced by the calcinations process. Traditional rotary-calcined metakaolins tend to be angular layered particles, whereas flash metakaolins contain spherical particles. As it has various advantages that used in constructions of bridges, water retaining structures, high rise buildings, off shore structures, mass concreting and nuclear power stations. On an industrial scale, the most metakaolins are obtained from a three-stage method that comprises a selection/grinding process, then calcination of raw Kaol for several hours in a rotary kiln, followed by grinding of the burned material [41–43].

5 Materials present in self compacting concrete

Self compacting concrete is a composition of cement, fine aggregate, coarse aggregate, water and super plastizer. These five raw materials play an important role in the manufacturing of concrete. By varying the properties and amount of above five materials, the properties of concrete will changes. The various raw materials used in aggregates of cement concretes as shown in the Fig. 7 and those materials play a major role of concrete manufacturing process. Cement is the main ingredient in manufacturing of concrete. Cement is a water-based binder used to bind other building materials together. It is used in the production of mortar and concrete during the construction process. The characteristics of concrete will be highly affected by changing the cement content. The cement used in the construction work is ordinary Portland cement of 53 grade confirming to IS 12269-1987. Concrete is formed when port land cement creates a paste with water that binds with sand and rock to harden. SCC compatibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure for mix design of SCC. The properties of different constituent materials used in this investigation and its standard tests procedures for acceptance characteristics of self compacting concrete such as slump flow, V-funnel and L-Box are presented [44, 45].

Fine aggregates are usually sand or crushed stone that are less than 9.55 mm in diameter. Typically the most common size of aggregate used in construction is 20 mm. A larger size 40 mm is more common in mass concrete. Larger aggregate diameters reduce the quantity of cement and water needed. The fine aggregates of size ranges between 0.075 and 4.75 mm. The fine aggregate used in the experimental

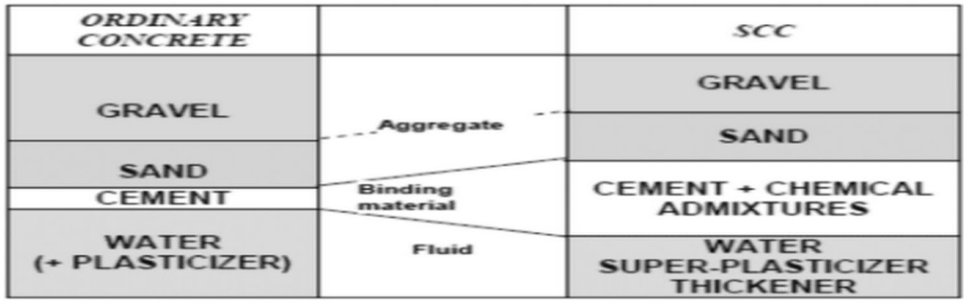

Fig. 7 Aggregates used in the cement concrete

program is river sand. The fine aggregate are selected as per IS-383 specifications. Generally coarse aggregate is blended with finer aggregates to fill in the spaces left between the large pieces together. This reduces amount of cement paste required and decreases the amount of shrinkage that could occur aggregate of size more than 4.75 mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used in this experimental work is 20 mm and 16 mm. The coarse aggregate are selected as per IS-383 specifications. Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength of cement gel, the quantity and quality of water are required to be looked into very carefully. Excessive impurities present in the mixing water not only affect the setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability and reduced durability [46–48].

5.1 Properties of self compacting materials

Properties of concrete are influenced by many factors mainly due to mix proportion of cement, sand, aggregates and water. The value of strength which is not more than 5% of the test results are expected to falls. Quality tests on cements at construction site (also called field tests on cement) are carried out to know that the quality of cement supplied at site. It gives some idea about cement quality based on colour, touch, feel and other tests. The cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand. Super plasticizers also known as high range water reducers, are additives used in making high strength concrete. Plasticizers are chemical compounds that enable the production of concrete with ca. 15% less water content. Super plasticizers allow reduction in water content by 30% or more. The mix composition was selected to satisfy each and every one performance criteria for the concrete in both the fresh state and hardened state. Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve the target strength in structures [49, 50]. So, the concrete mix design can be stated as concrete mix = cement: sand: aggregates. To achieve the desired combination of properties in fresh SCC mixes:

- The fluidity and viscosity of concrete paste was adjusted and balanced by careful selection and proportioning of the cement and additions, by preventive the water to powder ratio then by adding a super plasticizer or a viscosity modifying admixture. Perfectly controlling these elements of SCC, their compatibility and interaction is that the key to achieving good quality filling ability, passing ability and segregation resistance.
- The coarse to fine aggregate ratio in the concrete mix is reduced so that the individual coarse aggregate particles are fully surrounded by a layer of mortar. This may reduce and weak aggregate interconnect and bridging when the concrete mix passes through the slender opening or gaps between the bars and shows increase in the passing ability of self compacting concrete (SCC).

Detailed specifications for cement concrete provides a step by step description and specifications for various phases of concrete production and application such as materials, mix proportions, mixing of content, workability, formwork, laying and curing. After completing the mix proportioning of materials concreting is done to represent the characteristics. The quantity of cement, fine and coarse aggregate, water, super plasticizer for each batch of proportion as mentioned in the design of SCC [51, 52].

5.2 Fresh properties of self compacting concrete

5.2.1 Fresh concrete

Fresh concrete can be easily molded into any designed shape in construction. It can be prepared on the spot and may give a wide range of properties from easily available raw materials. Concrete remains in its fresh state from the time it is mixed until it sets. During this time the concrete was handled, transported, placed and compacted. Properties of concrete in the fresh state are very important because they influence the quality of hardened concrete [53, 54].

5.2.2 Fresh state tests on SCC

The main characteristics of self-compacting concrete (SCC) in the fresh state are that, with no need for vibration, SCC can completely fill the formwork and surround the reinforcement adequately (even in densely reinforced areas), leaving no voids and no segregation during the casting. For that, besides high fluidity, the SCC has to show good capacity to flow and pass between the reinforcement bars, as well as an excellent capacity to flow like a "viscous fluid" [55, 56].

5.2.3 Slump flow test

The concrete slump flow test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is shown in Fig. 8 as used to ensure uniformity for different loads of concrete under field conditions. In slump flow test they are two major parameters i.e. yield stress and viscosity. In the slump flow test, the rate of movement is small and the concrete is at rest when the slump is measured, i.e. the shear rate is zero or near zero throughout, and therefore a relationship between slump and yield stress might be expected. The test, normed by EN 12350-2, owes part of its diffusion to its simplicity, low cost of the equipment used, the easy interpretation of results, and the fact that it can be performed both on site and in the laboratory [43–45, 94].

6 Casting properties of concrete

After mixing the concrete the fresh properties are carried out. Then the concrete is placed into the moulds. Then the cubes, cylinders and prisms were tested for their compressive strength, split tensile strength and flexural strength respectively. The inner sides of each mould were coated with one coat of shuttering oil for de-moulding the specimens easily. With proper fitting and oiling for easy removal of specimens the moulds should be prepared carefully. Each layer was compacted manually by using bullet headed tamping rod. Top layer was finished and leveled uniformly by using trowel to coincide with the top level of mould. After 24 h, the casted specimens were demoulded and then immersed in water tub for curing. Concrete shall be transported from the drum mixer to the work area without any loss of time because if it is late there will be an addition of water to give workability but it leads to segregation of concrete. Place the concrete into the moulds with a trowel. The concreting should be done in layers of 5 cm each. The placing of concrete in the various specimens for the analysis of comprehensive and tensile strength as shown in the Fig. 9. For each layer proper compaction is required by tamping bar. After compacting top layer, the moulds are vibrated on the vibrating table for better mixing and bonding. Test cubes should be demoulded between 16 and 24 h after they have been made. After this period of time the concrete has not achieved sufficient strength to enable demoulding without damaging the cubes then demoulding should be delayed for further 24 h. When removing the concrete cube from the mould, take the mould apart completely. Take care not to damage the cube because, if any cracking was caused, the compressive strength may be reduced. The specimens are removed curing days [57–60].

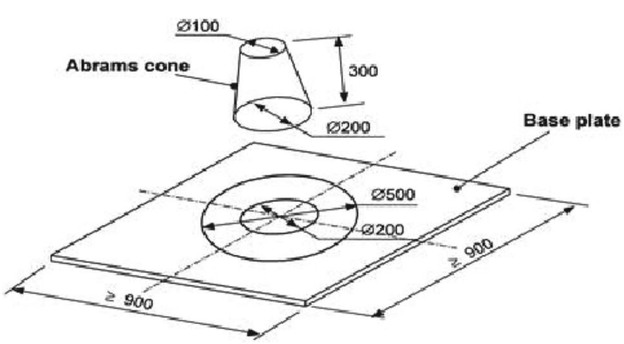

Fig. 8 Schematic diagram of slump flow board with abram cone

Internal curing helps concrete realize its maximum potential in a simple, economical and sustainable way. Internal curing improves hydration reduces early cracking, reduces chlorides, reduces curling and improves durability all of which extend the concrete's service life [61, 62].

6.1 Curing processes of the concrete

Curing is most important process in concreting. Concrete strength increases with the age of curing. The curing temperature of water in the curing tank should be maintained at 27–30 °C. If curing is in a mist room, the relative humidity should be maintained at not less than 95%. Curing should be considered as long as possible up to the time of testing. Generally we are curing the cubes and cylinders are two types [63, 64].

6.1.1 Water curing processes

The specimens should keep in curing tank for better improvement in strength. Generally curing is done by pounding the curing tanks. The water used for concrete curing should be free from salinity, scrap, vegetation and chemicals. The water curing of various concrete specimens is shown in Fig. 10. In order to provide adequate circulation of water, adequate space should be provided

Fig. 9 Placing of concrete in the various specimen

Fig. 10 Water curing of various concrete specimens

between the cubes and side of curing tank. Water curing is done by spraying or sprinkling water over the concrete surface to ensure that the concrete surface remains continuously moist. This prevents the moisture from body of concrete to evaporating and contributes in the strength gain of concrete.

6.1.2 Self curing processes

Self-curing concrete is achieved by means of replacing a part of aggregate by light weight aggregate or adding chemical admixtures. The specimen of various self curing concrete is shown in Fig. 11. The self-curing process of concrete takes

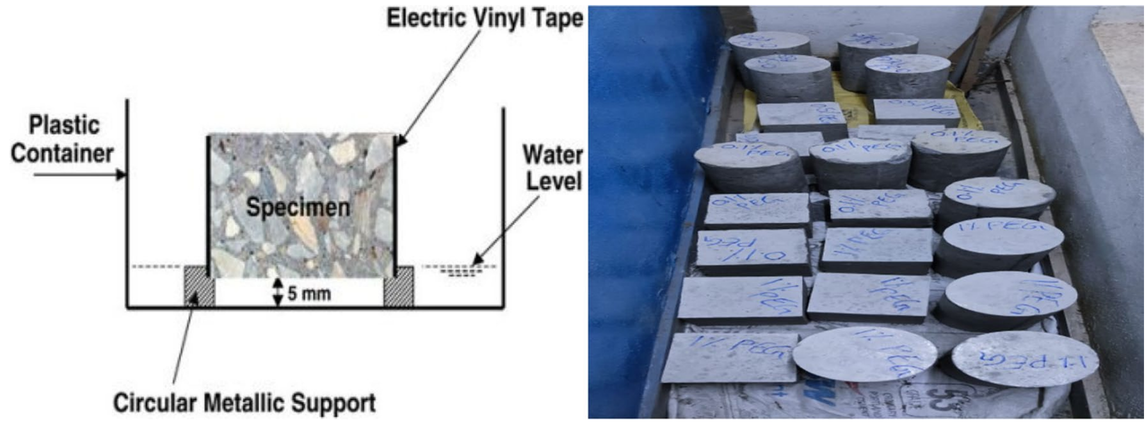

Fig. 11 Self curing of various concrete specimens

place from inside to outside, thus reducing the autogenously shrinkage and self-desiccation, especially for the high-performance concrete with relatively low water/binder ratio. There are not available for water then adds self curing agents to improve the strength. The durability and workability of self-curing concrete are improved, compared with conventional air-cured concrete, while the mechanical properties may be either improved or compromised due to the dual function of self-curing agent. [65–68].

Self-curing concrete has been broadly applied in the actual practice, mostly bridge decks and pavements. Self-curing concrete is one type of modern concrete, which cure itself by retaining water in it. The durability properties of self-cured SCC are comparable with the traditional cured specimens. The main reasons for discrepancies in the performance of concrete are due to the lack of proper compaction and curing. Hence there is a need of concrete that can flow easily through the congested reinforcement and attain better performance without the need of external curing techniques. Self-curing is done in order to fulfill the water requirements of concrete whereas self-compacting concrete is prepared so that it can be placed in difficult positions and congested reinforcements. This investigation was aimed to utilize the benefits of self-curing and self-compacting [69, 70].

6.2 Hardened properties of concretes

After complete the curing then conduct hardened properties at 7 and 28 days. Generally the hardened concrete properties are compressive strength, split tensile strength were tested in the concrete laboratory. The density of hardened concrete depends upon the unit weight of constituent materials and volume of void space. The carbonation of harden concrete by atmospheric CO_2 in connections with the corrosions of reinforcing steels. Here, the focus will be effects that carbon dioxide dissolved in water have on concrete. At atmospheric pressure, carbon dioxide will dissolve slightly in water, producing a solution of carbonic acid (H_2CO_3) with a pH of about 5–6. Now, it should be remembered that pure water by itself will attack concrete. The chemical reactions that can occur involve, first, the dissolution of carbon dioxide to form carbonic acid [71, 72].

6.2.1 Compressive strength of concretes

Compressive strength or crushing strength is the main property observed in the testing of cubes. Cubes are tested to calculate the compressive strength by applying gradual load in the compression testing machine. The compression testing is a common testing method that is used to measure the compressive force or crush resistance of material and capacity of material to recover after specified compressive force and even held over a defined period of time. The measured compressive strength of specimen shall be calculated by dividing the maximum load applied during the test by cross sectional area calculated from mean dimensions of the section shall be expressed to the nearest N/mm^2. Among many test applied to the concrete, this is given utmost important which has an idea about all the characteristics of concrete. The cubes of size $150 \times 150 \times 150$ mm were casted. After 24 h, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water [73, 74].

After curing, the specimens are tested for compressive strength as shown in the Fig. 12 by using compression testing machine of 2000 KN capacity (IS: 516-1959). The maximum load of failure was taken. A minimum of three specimens should be tested for determining the strength. The average compressive strength of concrete specimens was calculated. The compressive strength has been calculated by the formula:

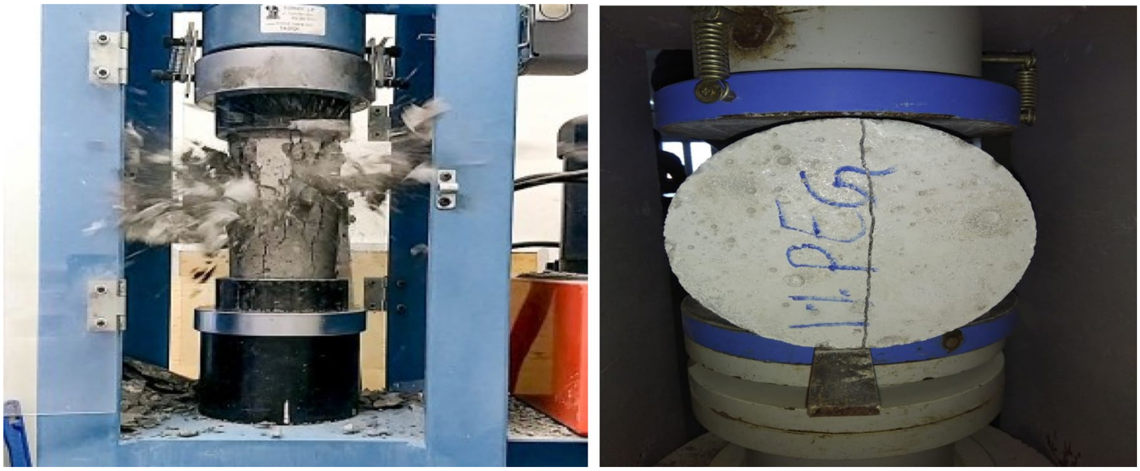

Fig. 12 Compressive strength test of the concrete

Compressive strength = Applied load/cross sectional area

= P/A

= load/area N/mm^2.

6.3 Split tensile strength of concrete

Split tensile strength is the most important property of concrete. Concrete is weak in tension. So that improve the tensile behavior of concrete, split tensile strength is important. The cracking takes place is a form of tension failure. It is important in reducing structure of cracks in the concrete. Cylinders are casted for calculating the split tensile strength. Moreover, the concrete is very weak in tension due to its brittle nature. Hence it is not expected to resist the direct tension. So, concrete develops cracks when tensile forces exceed its tensile strength. Therefore, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The procedure based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which similar to other codes like IS 5816 1999. One of the important properties of concrete is "tensile strength" as structural loads make concrete vulnerable to tensile cracking. Tensile strength of concrete is much lower than its compressive strength (that's why steel is used to carry the tension forces). It has been estimated that the tensile strength of concrete equals roughly about 10% of compressive strength. To determine the tensile strength, indirect methods are applied due to the difficulty of direct method. Noting that the values obtained of these methods

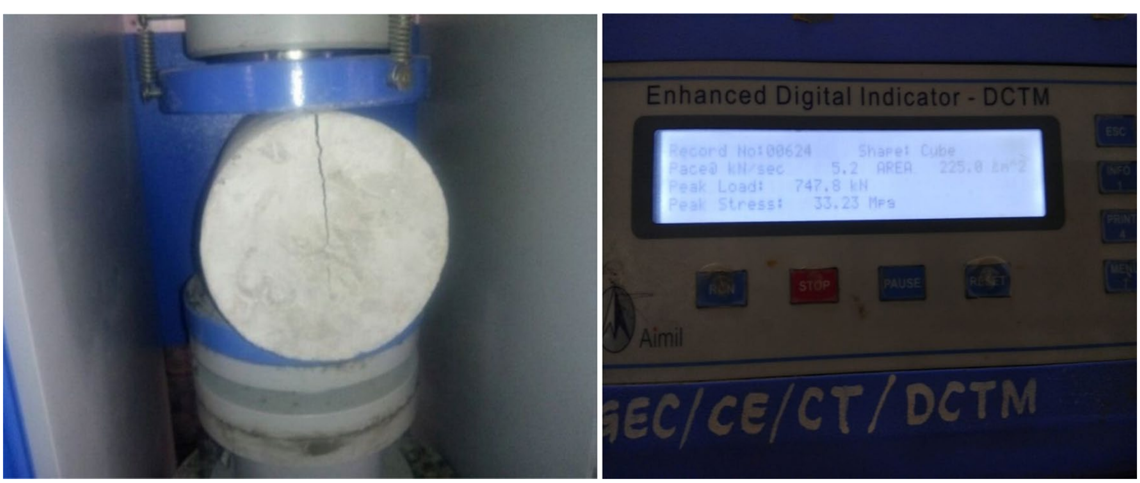

Fig. 13 Split tensile strength test of the concrete

are higher than those got from the uniaxial tensile test. The development of splitting tensile strength of concrete progressed in a manner similar to that of its compressive strength. However, it is possible that the interaction between the new cement paste and adhered mortar. The cylindrical specimens are also tested in compression testing machine as shown in the Fig. 13. The cylinders are placed in the axial direction by facing cylindrical face to the loading surface. The concrete is very weak in tension due to its brittle nature and not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to find out the tensile strength of concrete to determine the load at which the concrete members may crack [75, 76].

The cylinders are having a size of 150 mm diameter and 300 mm length. After 24 h, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water. After curing, the specimens are tested for split tensile strength using compression testing machine of 2000 KN capacity (IS: 516-1959). The maximum load at failure was taken.

The split tensile strength has been calculated by the formula

$$\text{Split tensile strength} = 2P/\pi LD,$$

where P is the failure load (applied load), L is the height of the cylinder specimen, D is the diameter of mould.

6.4 Durability of concrete

Durability can be defined as the capacity of structure to required performance during intended service period under the influence of degradation factors. Normally, the concrete is a durable material and requires a little or no maintenance during the life of structure. Durability of concrete depends on the mixed design proportions, workmanship of the work, placing, compaction of concrete and mechanical properties of concrete. Chemical resistance of concrete depends on the selection of materials; weathering action and improved further by introducing air bubbles into the concrete. The durable concrete will retain its original form as quality and serviceability when exposed to intended service environment. The quality of concrete depends on the quantity of cement and water, which decides the strength and durability of hardened concrete. A durable material helps in environment by conserving resources and reducing wastes and environmental impacts of repair and replacement. Concrete resists weathering action, chemical attack and abrasion while maintaining its desired engineering properties [77, 78].

As far as the durability indicators are concerned, SCCs generally show lower open porosity and sorptivity values. In fact, the sorptivity, which is a fundamental parameter controlling liquid transport in porous materials, and hence durability, is at least 30% lower in every case. While this finding is reasonable and expected in the case of mixtures containing cement replacement materials and/or lower water contents. Even a slight reduction in water content (SCC) resulted in significant alteration in permeability (as well as in sorptivity and porosity). Mixtures with cement replacement material (SCC) showed even more noticeable improvements in their durability properties. The correlation between adsorptions and porosity for self compacting concretes mixtures. As it can be observed there is a perfectly linear correlation between the two properties for the particular mix designs examined in this study. The larger porosity the more liquid in material can absorb. Similar correlations exist between sorptivity and chloride permeability. As per EFNARC Guidelines for SCC mix design, one of the most important differences between SCC and conventional concrete is the incorporation of a mineral admixture. A more fundamental approach is looking at the durability of self-compacting concrete by studying its pore structure and air-void system, and by investigating the transport mechanisms. The available durability results will be studied and summarized keeping in mind the fundamental mechanisms and driving forces. In this way some more general view on durability of self-compacting concrete will be obtained. Different concretes require different degrees of durability depending on the exposure environment and properties desired. The properties of water absorption relate directly to long-term durability of concrete. Appearance of pores, defects and crevices in concrete increases the water absorption in concrete, which affects the mechanical and durability properties. Concrete is a structural material and building surface skin, has the capacity to withstand nature's normal deteriorating mechanisms as well as natural disasters. Concrete can withstand these effects when properly designed [79, 80].

7 Effect of acid on the hardened of concrete

The behavior of acids on hardened concrete is conversion of calcium compounds into calcium salts of attacking acids. Hydrochloric acid with concrete produces calcium chloride, which precipitate as gypsum and nitric acid with concrete gives rise to calcium nitrate, as a result of this reaction, structure of concrete gets damaged. If the salt is soluble, the rate of reaction depends on the rate of dissolution of salts. Acid attack completely changes the hardened cement paste on the surface and destroys pore system of the hardened concrete. Therefore in the case of acid attack, the permeability of sound concrete is less important as compared to reaction that takes place. The severity of deterioration of concrete depends on the concentration of acid and temperature. The various effect of acid transformations in the concrete from fresh state to hardness state. In fact, no ordinary portland cement concrete is acid resistant. Durability is the age dependent parameter which was observed in curing with sulphate solution and acid solution for 30 days in cubes. The resistance of water curing and different curing regimes of concrete specimens was examined by the immersing cubes in 5% concentration of HCL to assess the chloride attack. The risk of acid attack and sulphate attack are reduced with different curing of concrete [81–83].

Plain concrete has low strength at tension and low strain at crack. Concretes are randomly distributed to control the crack arrest and increase the tensile strength. In Table 3 observed that the weight loss of self compacting concrete tube for 28 days in acid curing conditions. In general practice, the degree of attack increases as the concentration of acid increases. The effect of acid water on concrete beam structures is shown in the Fig. 14. The binding property of cement in concrete is a result of the hydration reaction products of cement and water. The water evaporation in fresh concrete is mold due to high temperatures, low humidity of air, high wind velocity may prevent the hydration and strength gain. The proper curing of concrete plays very important role for both strength and durability properties of the hardened concrete. By definition the strength grade of concrete, a standard 28-day period of water curing was required. Normally, the strength gaining continues beyond 28 days when there exists adequate moisture and temperature conditions [84, 85].

The hydration rate of cement increases with the increase in temperature, so that the gain of strength can be speeded up by the curing concrete in steam. There was only small change of pH value in the alkaline environment to high values in the first stage of hydration. The pH values after 28 days were comparable for all samples stored without changing environments throughout maturation. Due to the reaction of calcium ions with CO_2 from the air, calcite was detected in the thin layer covering the surface of liquids in all samples after a certain time. According to assumptions, the highest amount of portlandite was precipitated in an alkaline medium and lowest amount in an acidic media. The largest crystals have been precipitated in the water environment. The positive influence of test pieces aging in aqueous media on their mechanical properties (compressive and flexural strength) was demonstrated [86, 87].

Slightly lower compressive strength after 28 days were observed for samples immersed in an alkaline environment. This result corresponds to a different effect of pH environment on hydration compared to acidic and neutral media. The pH value of aqueous medium was increased with time. The amount of portlandite was decreasing only for sample with changed water. This was causing by formation of stronger links of alkali ions in the cement paste through the advancing hydration reactions and processes. By using of thermal analysis, the highest amount of portlandite in the sample stored in alkaline solution (especially with CaO) was detected. This effect can occurs due to higher calcium concentrations in the environment. Certain aggregates including siliceous (containing silica) will not be attacked by acid, but calcareous (containing calcium) aggregates readily react with acids. Mineral acids like hydrochloric, nitric, sulphuric and chromic acids are some of the most dangerous acids that affect the concrete. So it is necessary to study the deterioration effect on concrete due to sulphuric acid significantly lower amounts of free water were discovered in the samples aged in an alkaline environment [88–90].

Conversely, the higher amount of CSH was found in these samples. This phenomenon would correspond to faster hydration reaction course in this environment. The increase in water curing duration resulted in increases the compressive strength. The water penetrated through the top surface of specimen by capillary suction. The impermeable surface prevent the penetration of moisture inside the specimens, thus reduces the de polymerisation of silica, which is the reason for less expansion. The higher

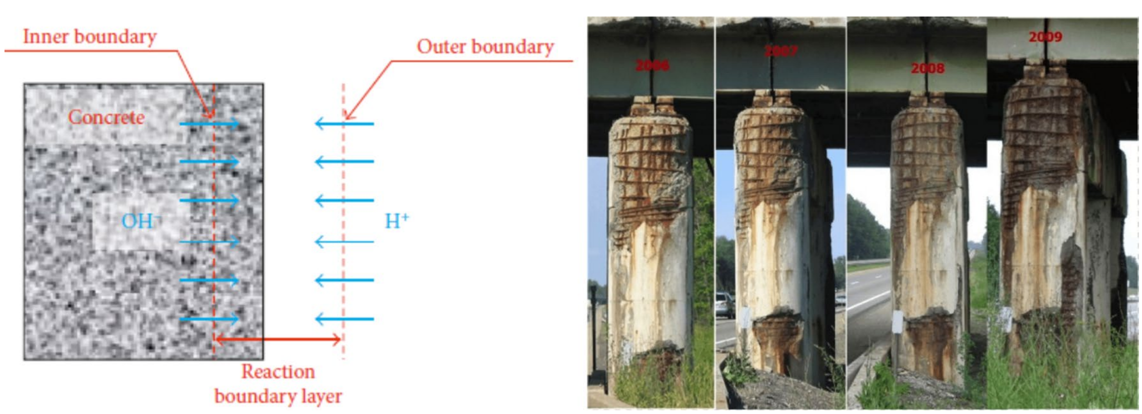

Fig. 14 Effects of acid water on the concrete beam structures

Fig. 15 Degradation of concrete structures from influence of aggressive chemicals

grade of concrete has more abrasion resistance than the lower grades of concrete due to better packing. The corrosion effect was reduced for higher grade concrete due to less w/c ratio. The degradation of concrete structures from influence of aggressive chemical is shown in Fig. 15. Water absorption is one of the important parameters, which affects the durability of structure due to the corrosion of steel reinforcement [85, 91].

The acid attack on the concrete will not cause deterioration in the interior structure of concrete without cement paste on the surface portion being fully deteriorated. The rate of acid attack is also depends on the capacity of hydrogen ions to be diffused through the cement gel (C-S-H) after calcium hydroxide ($Ca(OH)_2$) has been dissolved and leached out of the concrete. Pronounced increase in the early strength development, resulting in very economic stripping times for precast and in situ concrete. The rate of acid attack is also depends on the capacity of hydrogen ions to be diffused through the cement gel (C-S-H) after calcium hydroxide ($Ca(OH)_2$) has been dissolved and leached out of the concrete. Pronounced increase in the early strength development, resulting in very economic stripping times for precast and in situ concrete [68–70]. Admixtures generally, control setting and hardening properties of concrete, improve the workability and provide extra cementing properties. It is more importance to determine the effect of SCC to chloride, sulfate and other chemicals on the durability properties of concrete. This indicates that the increasing percent replacement levels reduced the passing ability of fresh concrete and thus indicating decreased workability. The weight loss of cubes immersed in sulphate solution increased as curing duration increased and decreased with increasing percentage replacement levels. To produce self-compacting concrete found that the SCC absorbed more water and had more permeable spaces than normal vibrated concrete possessing the same strength [92, 93].

8 Scope of self compacting concrete in the future applications

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve the performance with the help of innovative chemical admixtures and supplementary cementations materials. The own weight, filling formwork achieving full compaction in the presence of congest reinforcement. The hardened concrete was dense; homogeneous has the same engineering properties and durability as traditional vibrated concrete. Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around the congested reinforcement. The compressive strength and split tensile strength are main properties for determining the concrete strength. Self curing concrete contains a chemical agent that reduces the evaporation of water from its surface, primarily by reducing the vapor pressure at the concrete pore solution surface [94, 95].

Since SCC flow through the V-funnel test is a gravitational flow with large deformations, the three-dimensional smooth particle hydrodynamic (SPH) mesh-less numerical approach is preferred to solve the governing equations of SCC flow. The flow rate of SC-ECC is simulated by filling the V-funnel with square-grid mortar particles and random-inclined particles, allowing the material particles to flow through the funnel-outlet under the gravitational force. Self-compacting concrete with a similar water cement or cement binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to the lack of vibration giving an improved interface between aggregate and hardened paste. The strength development will be similar in maturity testing will be an effective way to control the strength development. A number of concrete properties may be associated to the concrete compressive strength, the only

Fig. 16 Scope of self compacting concrete in future applications

concrete engineering property that was routinely specified and tested [73, 74]. The compressive strength values of SCC cured under different regimes at 7 and 28 days. The scope of self curing concrete is shown in Fig. 16, the maximum load applied to the specimen shall be recorded and appearance of concrete and unusual features in the type of failure shall be noted. The increase in curing duration resulted in increases the compressive strength values [96, 97].

Due to low humidity hydration is not completed, so air curing caused reductions in compressive strength for all groups. Hardened concrete gains strength with time and testing these hardened concrete for quality check is important for structures. Self-compacting concrete with a similar water cement or cement binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to the lack of vibration giving an improved interface between aggregate and hardened paste. The strength development will be similar in all testing will be an effective way to control the strength development. A number of concrete properties may be associated to the concrete compressive strength, the only concrete engineering property that was routinely specified and tested. The maximum load applied to the specimen shall be recorded and appearance of concrete and unusual features in the type of failure shall be noted. The increase in curing duration resulted in increases the compressive strength values [98, 99].

The properties of fine aggregate affect the quality of paste and interfacial transition zone. The development of split tensile strength of concrete is similar to its compressive strength. The different age of curing in concrete influences the quality of paste and splitting the tensile strength. The main reasons for lower splitting tensile strength of concrete made with different age of curing are increase in porosity and distribution of pores. The resistance to indirect tension was significantly affected by the parameters and types of curing. Moreover, the concrete is very weak in tension due to its brittle nature. Hence, it is not expected to resist the direct tension. The usage of recycled aggregate reduces the strength properties of concrete mixes. The effect of curing was examined on the strength properties of concrete. The replacement level can be taken as optimum content since the test results on marginal decrease was noticed when it's compared with the natural aggregates irrespective of the concrete mix. The strength difference between the concrete specimens became high distinct in the beginning of curing itself [100, 101].

9 Conclusions

Mechanical properties of self-compacting concrete and conventional concrete such as compressive strength and split tensile strength should be conducted. Self-compacted concrete with self-curing agents and self compacting agents has also studied. The primary characteristics of self-curing concrete rely on the type of curing agent, particularly this type of concrete is deemed to be workable and flow able. Longer curing results in the higher compressive strength. The compressive strength is more when specimens are cured for 28 days. The cost for SCC is high due to addition of super plasticizers and adding of more cement content. But the main advantages of using SCC is reduces construction cost and also vibration cost. Therefore the labor cost will be reduced. From the analysis concluded that the partial replacement of ordinary portland cement with fly ash does not affect the properties of fresh concrete to perform as SCC. Use of metakaolin addresses the issue of environmental and economical aspect hence sustainability of concrete technology. Among the various properties of aggregate, the important ones for SCC are shape and gradation. Better water retention decreases the porosity in concrete leading to better gel formation. By this analysis it also observed that the SCC can be done for low and medium strengths. Self cured SCC specimens with minimum moisture loss exhibited superior performance in terms of compressive strength, open porosity and adsorptive. In concrete with self-curing compounds is very good alternative in water scarce areas and in high temperature regions. There are lots of papers available related to SCC have been published but no review paper available in the literature that is dedicated to SCC.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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